Ethanolysis of PLA using ChCl/ZnAc deep eutectic solvent for sustainable ethyl lactate production

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Introduction

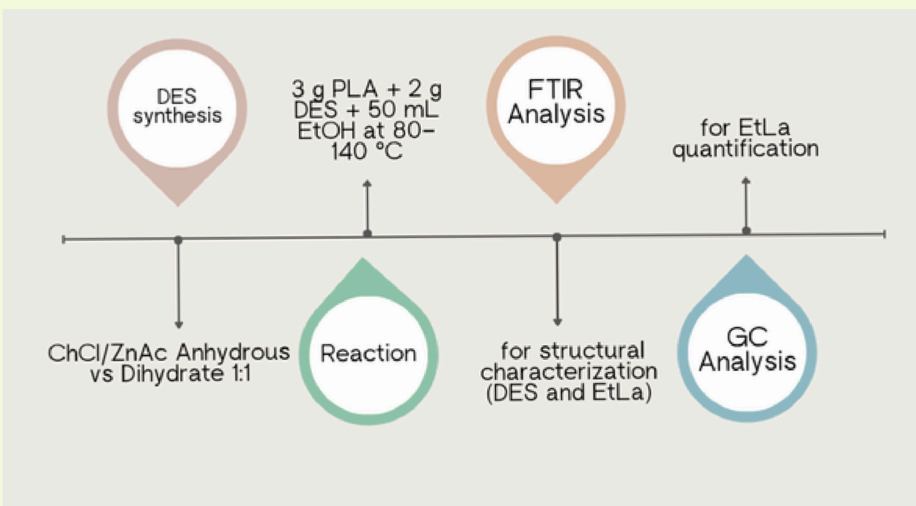
Polylactic acid (PLA) is a biodegradable polymer made from renewable sources. Its chemical recycling through ethanolysis produces ethyl lactate (EtLa), a valuable green solvent. Deep eutectic solvents (DESs) such as choline chloride/zinc acetate (ChCl/ZnAc) offer a sustainable catalytic system for this process, combining efficiency with environmental compatibility.

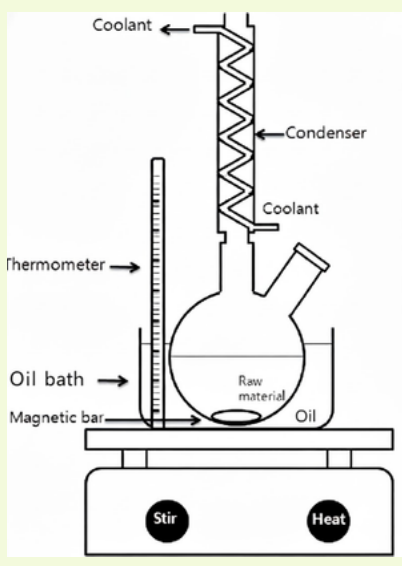
$$\text{PLA} + \text{EtOH} \xrightarrow{\text{catalyst}} \text{EtLa}$$

Objectives

- To compare catalytic activity of ChCl/ZnAc (anhydrous vs. dihydrate) DES formulation and to show the treatment of the PLA samples.
- To obtain kinetic model for the reaction of PLA + EtOH to get EtLa.
- To determine the optimum condition to maximise the conversion and the yield.

Methodology





Ackowledgements

FF is grateful for having a PhD fellowship from LSBU. A. Warne who gave the PLA samples.

References

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Results & Discussion

FTIR confirmed DES formation via hydrogen bonding and Zn^{2+} coordination. The anhydrous ChCl/ZnAc (1:1) DES achieved complete PLA conversion and up to 94.2% EtLa yield at 140 °C, while the dihydrate system reached a maximum of 88.9% under the same conditions. Reactions followed pseudo-first-order kinetics with activation energies of 21.72 ± 2 kJ mol^{-1} (anhydrous) and 22.12 ± 4 kJ mol^{-1} (dihydrate), confirming efficient catalysis under mild conditions.

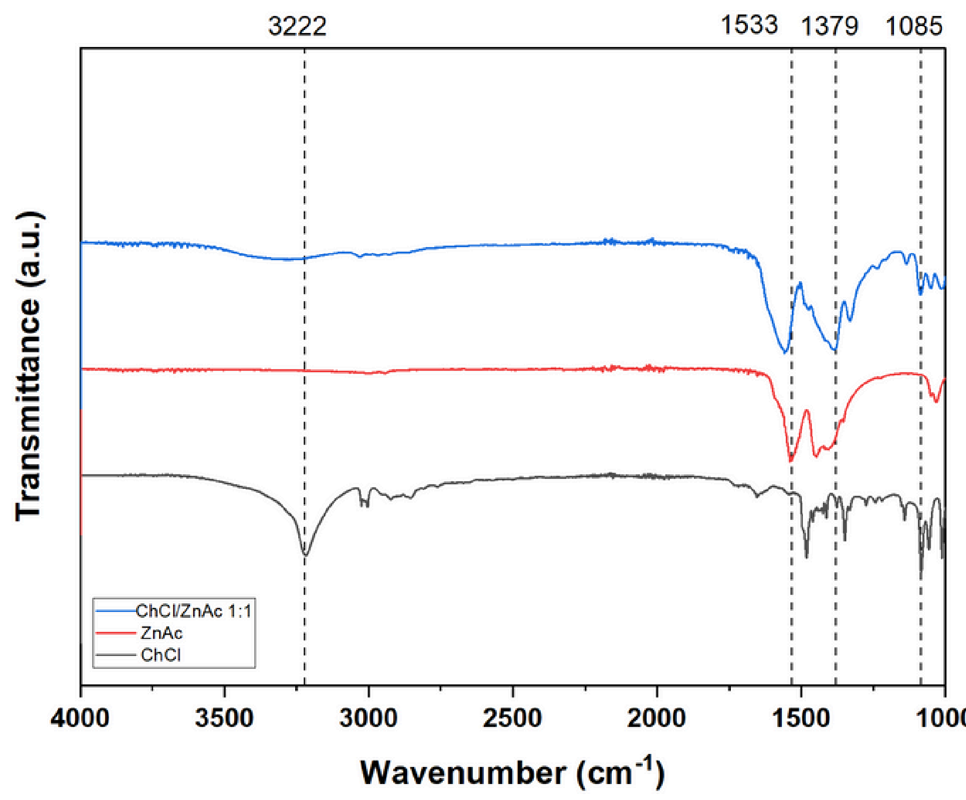

Figure 1: FTIR confirmed the DES formation via hydrogen bonding and Zn^{2+}

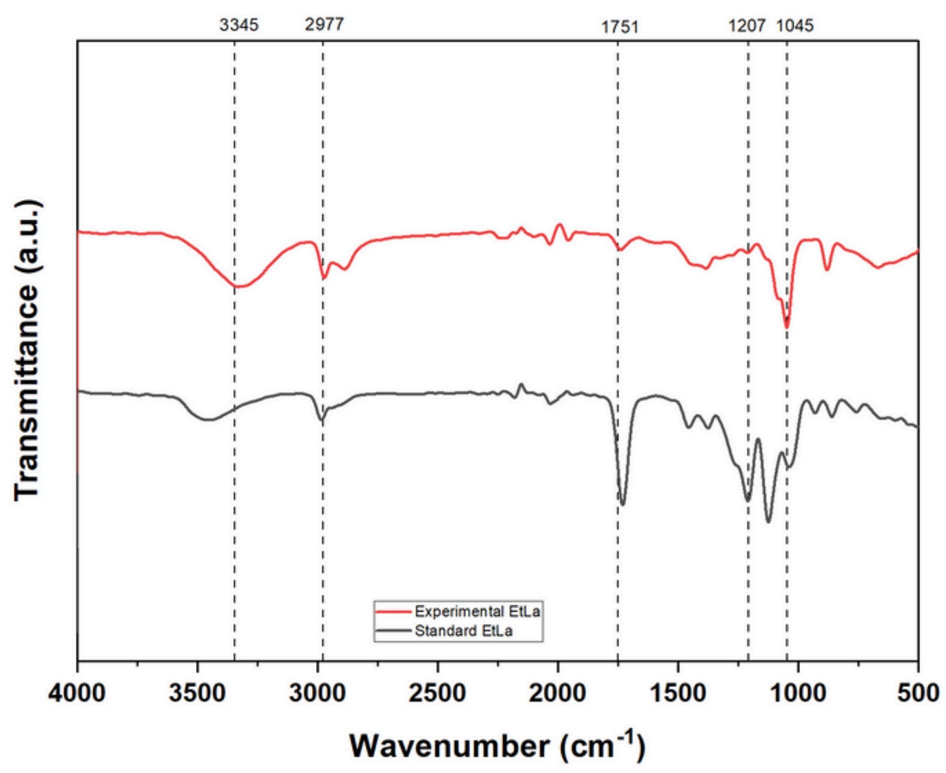

Figure 2: Standard EtLa and experimental EtLa

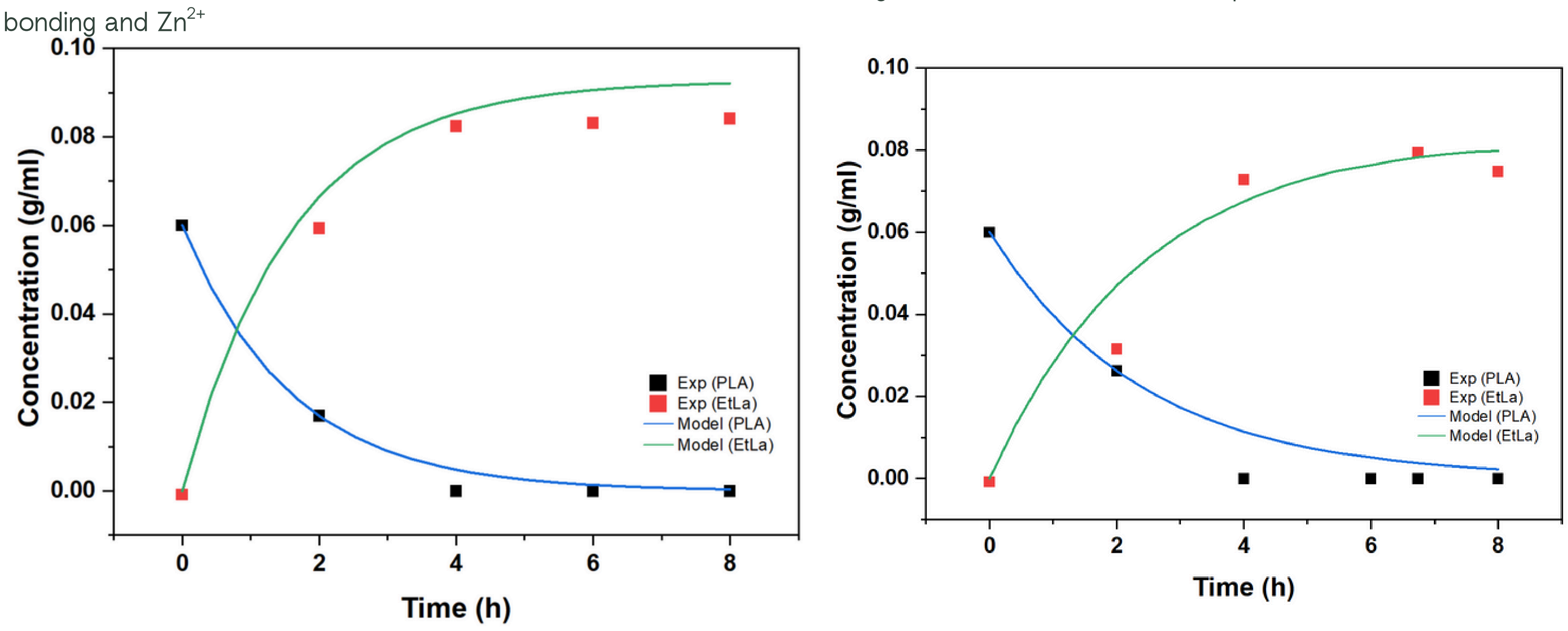

Figure 3: Kinetic model (experimental vs model data) using ChCl/ZnAc 1:1 DES, anhydrous (left) and dihydrate (right), at 140°C

Figure 4: PLA sample waste: toy, filament, and cup.

Model equations

$$C_{PLA} = C_{PLA}\,(1-X)$$

$$\frac{dx}{dt} = k(1-X)$$

$$ln\,\frac{1}{1-X} = kt$$

$$ln\,k = -\frac{E_a}{RT} + lnA$$

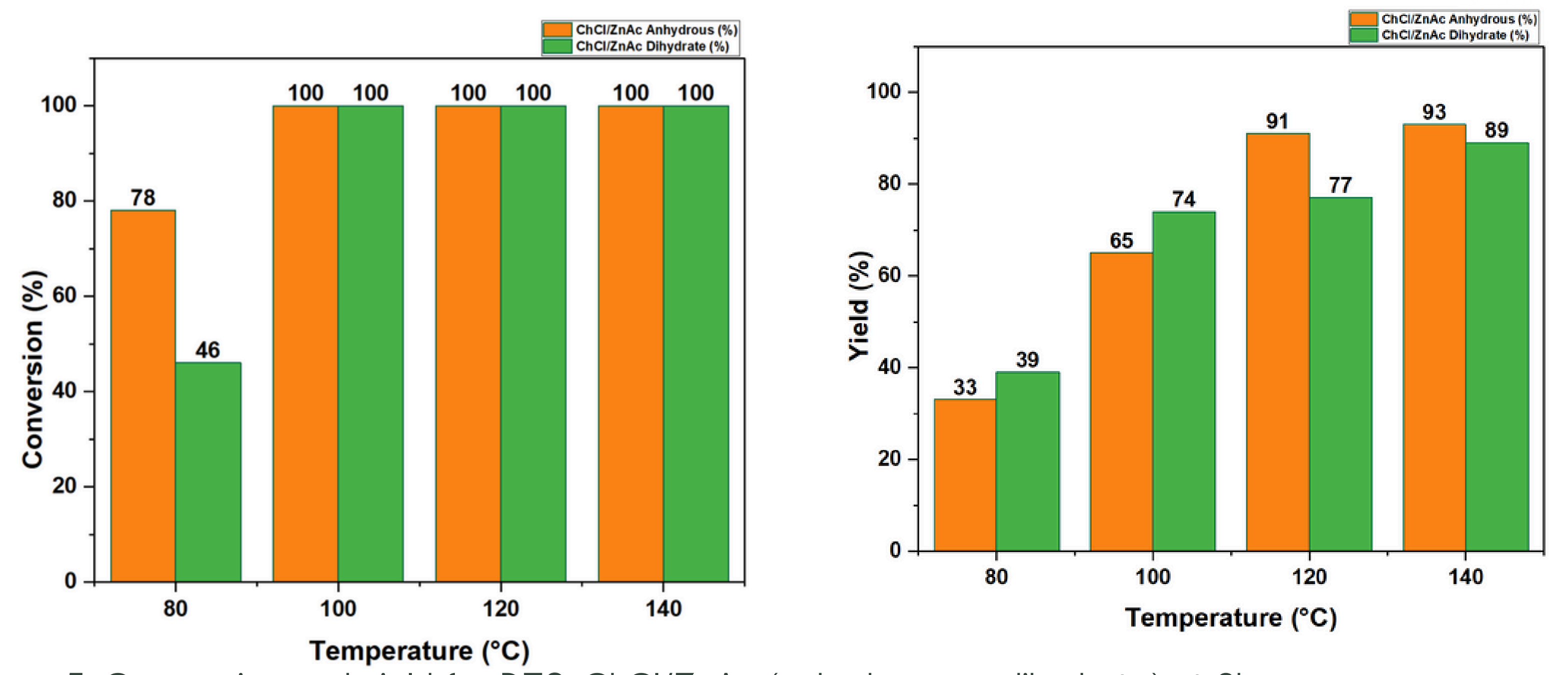

Figure 5: Conversion and yield for DES: ChCl/ZnAc (anhydrous vs dihydrate) at 6h

Table 1: : Experimental vs model concentration (g/mL) using DES ChCl/ZnAc anhydrous at 4h, 120°C for PLA waste

Sample	EtLa Exp	PLA Exp	EtLa Model	PLA Model
Cup	0.02814	0	0.08528	0.0048
Toy	0.04163	0	0.08528	0.0048
Filament	0.06914	0.5959	0.08528	0.0048

Conclusions

The study successfully concludes that the ChCl/ZnAc anhydrous DES is the superior and optimal catalyst for PLA ethanolysis, demonstrating high conversion to EtLa under 8h, at 140°C. The work establishes a validated kinetic model that accurately describes the reaction mechanism